Remarks/Arguments

Reconsideration of this application is respectfully requested.

In the office action of January10, 2007, claims 20, 21, 23-25, 30, 32, 35-40, 42 and 44 were rejected, primarily over the Helmer et al reference (US Patent 5,482,611). Claims 22, 26-29, 31, 34, 41, 45 and 46 were objected to and indicated allowable in self contained form.

According to the foregoing amendment, claims 20, 22, 25, 26, 29, 33, 35, and 43 have been amended, to seek to improve their definition of the present invention, and in some cases to define a scope of protection to which it is believed this invention should be entitled. As presented above, it is respectfully submitted claims 20-46 define the present invention in a way that is not disclosed in Helmer, and that the only motivation to modify Helmer to provide the subject matter of claims 20-46 would come only from the present disclosure, and not from any disclosures of the cited references. Therefore, it is respectfully submitted claims 20-46 are patentable over Helmer and the other cited references.

On April 9, 2007, undersigned and Applicant John Madocks had a chance to discuss this application with examiner Philogene, and the courtesy of that interview is gratefully acknowledged. Applicant explained the technical features provided by the invention, and the language of the claims was discussed. Examiner Philogene said he was satisfied that the term "nozzle" as recited in independent claims 20, 30, 36, 39 and 44 is a physical device, and that he understood the remaining points presented by the applicant, both in the interview and in the comments below. The examiner indicated he would consider those points, and may want to research the application and that if he wanted additional input from the applicant, he would contact the undersigned. In addition, the examiner indicated that once he had considered the issues presented by the applicant, and had drawn conclusions in relation to the art, he would contact the undersigned and the applicant to let them know his conclusions. Both applicant and the undersigned expressed their appreciation for those courtesies.

Regarding the substance of the interview, applicant presented comments as to why the independent claims are not disclosed or suggested by the Helmer et al reference. Specifically;

1. **Independent claims 20, 30, 36, 39 and 44** define, *inter alia*, applicant's concept of a plasma source that includes a **nozzle as a structural feature, and also define the nozzle as having a width that is less than the width of the discharge cavity.** Thus, these claims seek to define the nozzle 6 in applicant's plasma source and its width relative to the width of discharge cavity 26. The Helmer et al reference does **not** include a nozzle as a structural feature of the plasma source, and applicant believes this is an important distinction because:

   The physical nozzle of the plasma beam source performs a critical function for plasma enhanced chemical vapor deposition (PECVD) processes. Namely, the nozzle enables long term operation of a PECVD process by preventing coating build up on the internal electrode. Please refer to Figure 4 of the application.

   To accomplish a PECVD process, a precursor gas is mixed with non-condensing gases such as argon, oxygen and nitrogen in the presence of a plasma. The plasma energy breaks down the precursor and enables a chemical process resulting in condensable species formation. These condensable species land on surrounding surfaces and stick (condense). In the ideal condition, the condensation occurs on a substrate and a desired coating is formed. In reality, in addition to the substrate, all plasma facing surfaces are coated along with the substrate.

   For instance, an SiO_2 coating can be deposited by introducing a vaporized precursor gas such as hexamethyldisiloxane (HMDSO) and oxygen in a plasma. Methyl groups from the HMDSO are broken off and the oxygen combines with the silicon to form SiO_2. The SiO_2 molecule, having a low vapor pressure, condenses on the first surface it comes in contact with. When a substrate is placed in proximity to the plasma, an SiO_2 coating forms on the substrate.

PECVD is well known and has been extensively used, particularly in semiconductor fabrication. In typical semiconductor PECVD systems a parallel plate reactor is implemented with a flat electrode plate positioned over a silicon wafer substrate. In this reactor both the wafer and the electrode are exposed to the plasma glow and during the PECVD coating process the electrode is coated along with the substrate. Over time, the coating buildup on the electrode becomes detrimental to source operation. To maintain the electrode, the reactor is routinely etched back using a fluorinated gas. After the electrode is etched clean, the PECVD wafer coating process is resumed.

In a batch application such as semiconductor wafer coating, frequent etch back cycles are viable. However, for continuous applications such as roll to roll coating or inline glass coating, etch back cycles are not practical. In such continuous applications, a PECVD source must operate for many hours or even days without excessive coating buildup on the plasma electrode.

For roll to roll and inline continuous applications the Plasma Beam Source (PBS) is an enabling, revolutionary development. The PBS allows a PECVD process to run for hours or days without detrimental electrode coating. The PBS nozzle plays a critical role in solving the PECVD electrode coating problem. Illustration A below shows a section view of the PBS with a substrate and an external monomer gas source. Illustrations B and C (below) show a PBS in operation with oxygen gas.

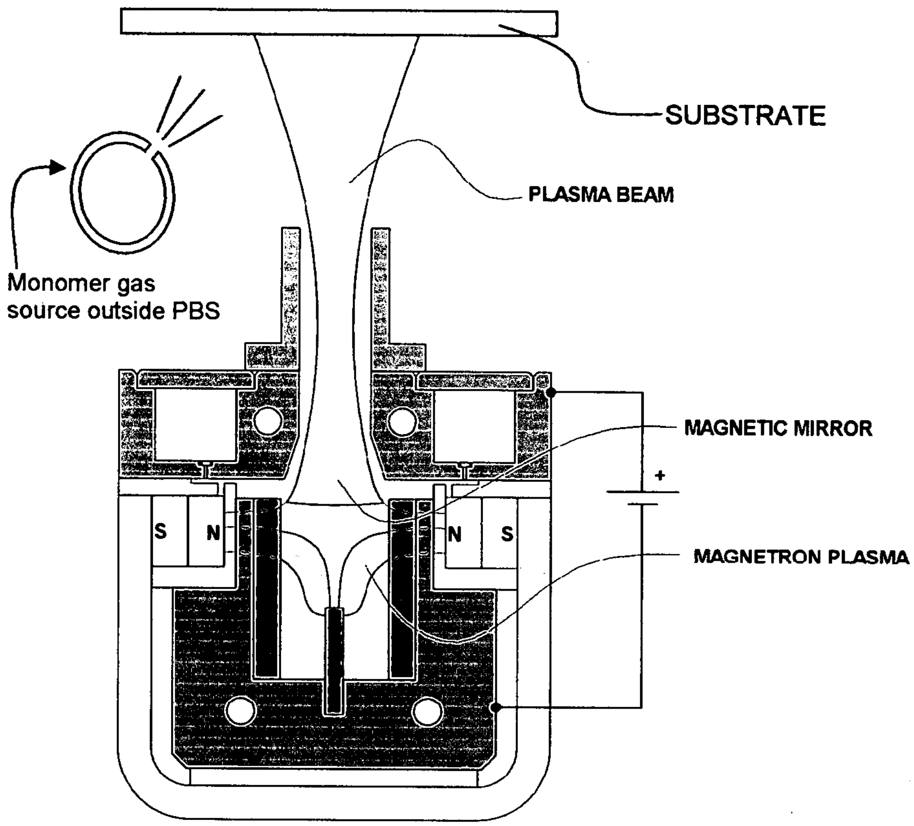


Illustration A: Section View of the Plasma Beam Source™

When the PBS is used in a PECVD process, the reduced dimension nozzle provides several key benefits:

- The nozzle blocks a significant portion of the discharge cavity opening and therefore limits the influx of precursor gas and condensable species into the discharge cavity.
- Since all the non-condensing gas exiting the PBS must flow through the nozzle, the flow of this gas through the narrow opening produces a mass flow that opposes the inflow of gas from the chamber.
- All the non-condensable gas fed into the PBS is forced to exit through the nozzle. This gas flow is directly co-incident with the PBS mirror plasma in the nozzle. The confluence of the gas and the plasma increases the density of the exiting plasma beam.

- Though the PBS discharge cavity sputter targets are made of a low sputter rate material to minimize sputter contamination of the PECVD process, the nozzle serves to block sputtered flux from exiting the PBS. The effectiveness of this is demonstrated when a copper internal cathode is used and a clear silicon dioxide PECVD coating is deposited on a substrate. Upon inspecting the coating, the film is clear. If copper oxide were sputtered from inside the PBS discharge cavity, a black (copper oxide) film would be seen on the substrate.

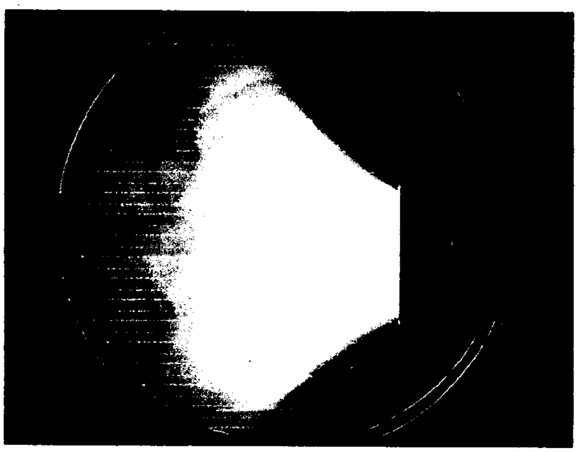


Illustration B. Active PBS™ with Oxygen Gas

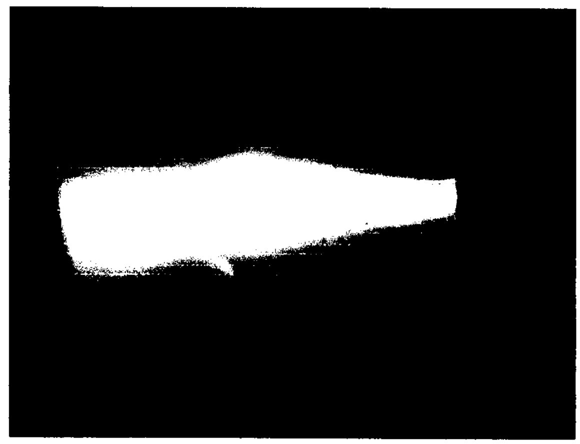


Illustration C. End View of Active PBS™

The overall effectiveness of the reduced dimension nozzle is demonstrated in two ways: 1) After many days of PECVD coating processes the internal electrode remains free of insulating coating buildup. If the nozzle is removed and the coating processes are repeated, the internal electrode becomes coated quickly. And, 2) Using the PBS for a PECVD coating process, an extremely high deposition rate is achieved. For instance, SiO2 coatings are deposited at dynamic rates exceeding 1,000 nm-m/min. Competing PECVD source technologies such as parallel plate reactors have deposition rates typically less than 100 nm-m/min. This is a testament to the high density of the PBS plasma exiting the nozzle.

The PBS is the only source for PECVD that effectively maintains the plasma generating electrode in an uncoated state while still enabling high deposition rates. Other sources have discharge cavities, for instance Inductively coupled

plasma (ICP) sources and Electron cyclotron resonant (ECR) sources. However, in these sources, as with Helmer, the cavity is exposed to the substrate process region and condensable species more readily migrate into the discharge cavity coating the electrode.

Beyond PECVD applications, the reduced dimension nozzle allows the PBS to operate in a reduced pressure chamber. Normally, for a sputter magnetron cathode, the surrounding vacuum must be maintained in the millitorr range. With the PBS, the nozzle separates and isolates the internal discharge cavity magnetron from the vacuum chamber. This allows the PBS to operate in a chamber with vacuum levels in the 10^{-5} torr range. This is demonstrated when the PBS is used to pre-clean a plastic web substrate in an aluminum evaporation system. In these so called metalizing coaters the process of evaporation takes place at 10^{-4} or 10^{-5} Torr. A magnetron cathode cannot operate at these pressures. With the nozzle isolating the discharge cavity from the evaporation chamber, the PBS is able to operate and deliver a dense, uniform plasma to the substrate.

For the foregoing reasons, it is respectfully submitted that independent claims 20, 30, 36, 39 and 44, which define, *inter alia*, applicant's concept of a plasma source that includes a nozzle as a structural feature, and which also define the relative width of the nozzle to the width of the discharge cavity, are not disclosed or suggested by Helmer. Moreover, none of the other cited references discloses or suggests anything that would motivate one skilled in the art to modify Helmer to provide such a feature. Therefore, it is respectfully submitted independent claims 20, 30, 36, 39 and 44 are patentable over Helmer and the other cited references. Moreover, it is respectfully submitted that in light of the foregoing remarks, there should be no doubt that the claims are limited to such a concept. Moreover, at the telephone interview, the examiner indicated he was satisfied that a nozzle, as reflected in the independent claims, is a physical device. However, in the event the examiner were to agree that applicant's concept of a plasma source that includes a nozzle as a structural feature, where the nozzle has a width relative to the width of the discharge cavity as defined in claims 20, 30, 36, 39 and 44 is

patentable, but that modification of the language of the claims is needed to clearly and unequivocally limit the claims to that feature, the examiner is encouraged to make language suggestions for modifying the claims.

2. **Independent claims 37 and 38** seek to define, *inter alia*, applicant's concept of a plasma source in which a cusp magnetic field is formed by magnets disposed exterior of the discharge cavity generally facing one another for creating a cusp magnetic field within said discharge cavity and having a null region. Thus, in applicant's Figure 1A (reproduced below), applicant's magnetic null region 25 is formed within the discharge cavity by the magnets 1 and 2 that are facing one another (see also paragraph 0034 of the application for a description of what magnets "facing each other" means). The Helmer et al reference provides a magnetic null region (1) that is outside the cavity of the cathode electrode 123, and the magnets of Helmer do not face each other in the manner provided by the present invention. This distinction is important for several reasons:

   - <u>Facing magnets allows the nozzle opening to be narrow</u>
     Facing, cusp magnets produce a strong magnetic mirror field through the nozzle aperture resulting in a narrow, dense plasma beam. This can be seen in Illustration C (above) and in applicant's FIGS 1A, 3 and 4 (below).

FIG. 1A

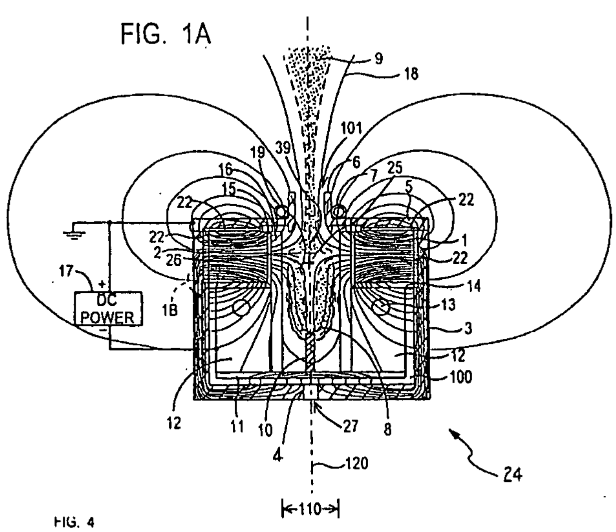


FIG. 3

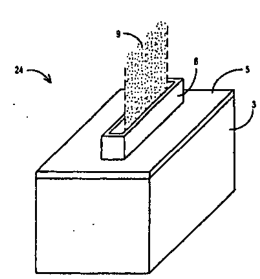
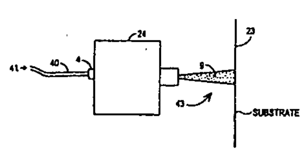


FIG. 4

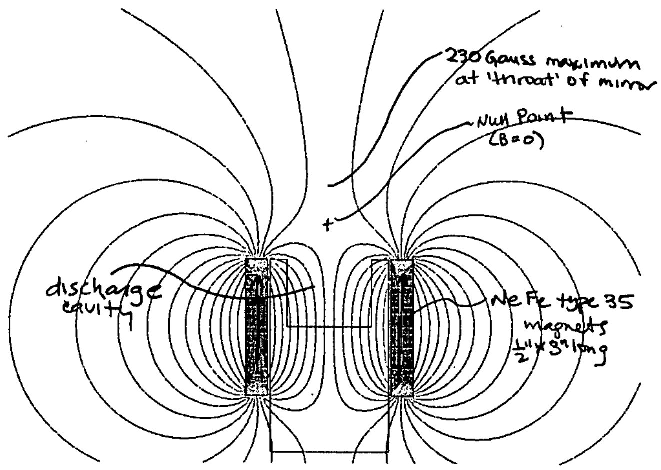


The exiting beam is tightly confined because the beam width is proportional to the strength of the magnetic field in the nozzle.

The gyro radius of electrons traveling along field lines is inversely proportional to the magnetic field strength. As the magnetic field strength increases, the gyro radius decreases. The gyro radius of electrons trapped in the nozzle magnetic mirror is proportional to the width of the plasma at the mirror: A larger gyro radius spreads out the electron density at the mirror and widens the region of ion creation. With the facing magnet design, a strong magnetic field in the nozzle is generated and the resulting plasma beam is very narrow in the nozzle. This, in turn, allows the nozzle aperture to be narrow, and all the benefits of the reduced dimension nozzle are enhanced.

- <u>A strong mirror magnetic confinement region is formed</u>
  Facing magnets produce a strong magnetic mirror impedance for electrons leaving the internal, discharge cavity magnetron. This promotes and produces a dense plasma emanating out of the PBS.
  Exhibit A (attached) is provided to further illustrate the difference between upward facing magnets per Helmer, and Window and Harding and inward facing magnets per Madocks in the present invention. Exhibit A provides a general comparison of the upward facing magnets of Helmer, and Window and Harding, and the inward facing magnets of Madocks (the present invention). Illustration D below shows the magnetic fields produced in Helmer's upward facing magnets.

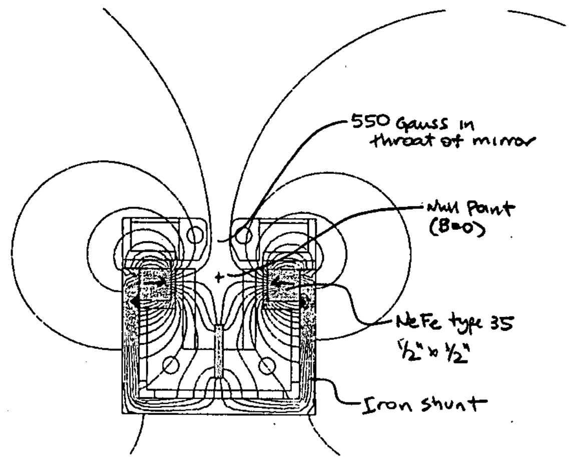
Illustration D



Helmer et al.
Magnetic Field Analysis

This configuration produces a null point above (and outside of) the discharge cavity. As the magnetic field lines close over the null point farther away from the discharge cavity, the field increases in strength. As electrons move from the null region to this region of increased field, they encounter and are impeded by the magnetic mirror effect. As is known, electron impedance increases as the difference between the weak and strong magnetic field regions increases. In Helmer et al., this ratio is between 0 at the null point and 230 gauss at the maximum mirror region. As shown in Illustration E (below), by facing the magnets as in Madocks, the maximum mirror region field strength is significantly increased.

Illustration E



Madocks PBS
Magnetic Field Analysis

The maximum magnetic field strength in the mirror region is 550 gauss. Note to that the magnets used in the Helmer et al. analysis (Illustration D above) are neodymium iron type 35 0.5" wide by 3" tall.

- In the Madocks analysis (Illustration E above) the same neodymium iron magnets are only 0.5" wide by 0.5" tall. Therefore, the stronger mirror region was created by magnets 1/6th the size.

- <u>The overall source is compact</u>
  As is described above in the comparative magnetic field analysis; a strong magnetic mirror is created in the present invention with small magnets. Also, inward facing magnets allows the top nozzle to fit directly over the discharge cavity. The result is a compact, space saving plasma source can be made. This is important because vacuum systems are very expensive and space is at a premium. Also, existing large area vacuum coating

systems have existing port often for devices such as magnetron sputter cathodes. With the compact size of the PBS, one or two PBS can fit into a magnetron cathode flange.

- <u>Internal cavity electron confinement is made easier</u>

  An important aspect of the present invention is electron confinement in two of the three axial magnetic field line regions. (Please refer to the Patent Application paragraph [0067].) As is related, two of the three axial field regions pass through the cathode liner. This important confinement aspect is easily accomplished by inward facing magnets. With inward facing magnets, the two axial field regions pass through the walls of the discharge cavity. With upward facing magnets per Helmer et al., only one

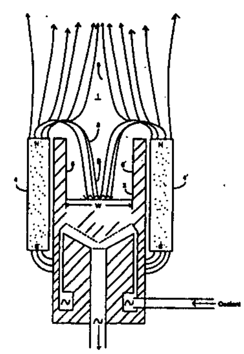


FIG. 1A

axial region passes through the container. The second annular planar axial region passes out the top of the source. In Figure 1A in Helmer et al.(below) this axial region passes out of the magnets 4 and does not pass through a cathode wall.

This will result in a poorly performing source in comparison to the source of the present invention.

For the foregoing reasons, it is respectfully submitted that independent claims 37, 38, which define, *inter alia*, applicant's concept of a plasma source in which a cusp magnetic field is formed by magnets disposed exterior of the discharge cavity generally facing one another for creating a cusp magnetic field within said

discharge cavity and having a null region, are not disclosed or suggested by Helmer. Moreover, none of the other cited references discloses or suggests anything that would motivate one skilled in the art to modify Helmer to provide such a feature. Therefore, it is respectfully submitted independent claims 37, 38 are patentable over Helmer and the other cited references. Moreover, it is respectfully submitted that in light of the foregoing remarks, there should be no doubt that the claims are limited to such a concept. However, in the event the examiner were to agree that applicant's concept of a plasma source in which a cusp magnetic field is formed by magnets disposed exterior of the discharge cavity generally facing one another for creating a cusp magnetic field within said discharge cavity and having a null region is patentable, but that modification of the language of the claims is needed to clearly and unequivocally limit the claims to that feature, the examiner is encouraged to make language suggestions for modifying the claims.

3. **Independent Claim 35** has been amended to focus on the applicant's source as an improved PECVD apparatus. The claim defines, inter alia, an enclosure defining a cavity; <u>a nozzle extending outwardly from the cavity; a</u> cusp magnetic field with a second portion producing a mirror confinement region passing through and out of said cavity <u>through the nozzle, whereby a plasma generated in the cavity is directed from the cavity through the nozzle; and a monomer gas outside the cavity that is reactive with the plasma directed from the cavity</u>. It is respectfully submitted that Helmer does not disclose or suggest an enclosure defining a cavity, with a nozzle extending outwardly of the cavity, and a mirror confinement region passing out of the cavity and producing a plasma that is directed from the cavity through the nozzle, and a monomer gas outside the cavity that is reactive with the plasma. Moreover, it is respectfully submitted that none of the other cited references would motivate one of ordinary skill to provide such a concept. The invention, as defined in claim 35, is suggested only by the applicant's disclosure, and not by the cited references.

For the foregoing reasons, it is respectfully submitted all claims in this application

define the present invention in a manner that is patentable over the cited references. Reconsideration and favorable action is respectfully requested.

Respectfully submitted,

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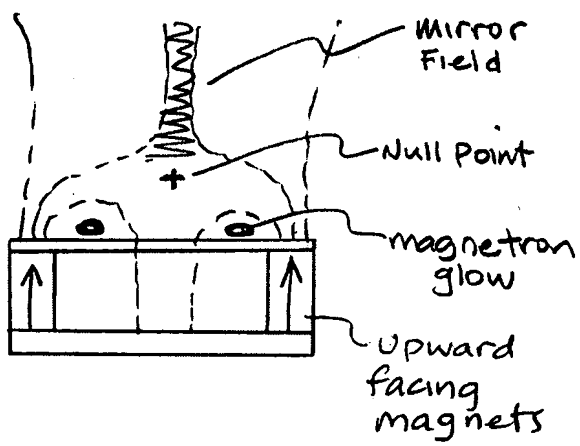
Application Serial Number 10/528,386

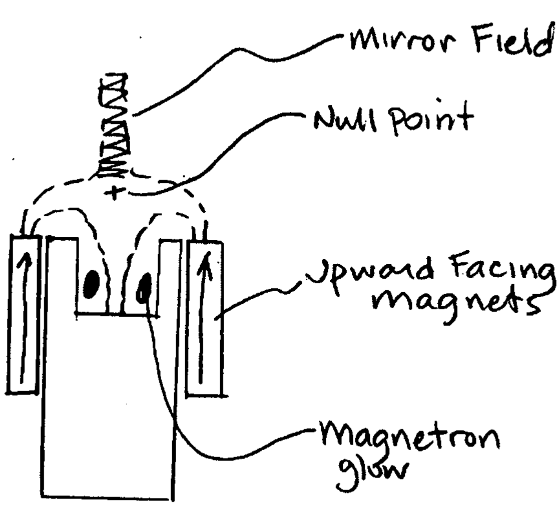
Exhibit A for presentation to Examiner in connection with PBS Response to Office Action

Window and Harding[i]



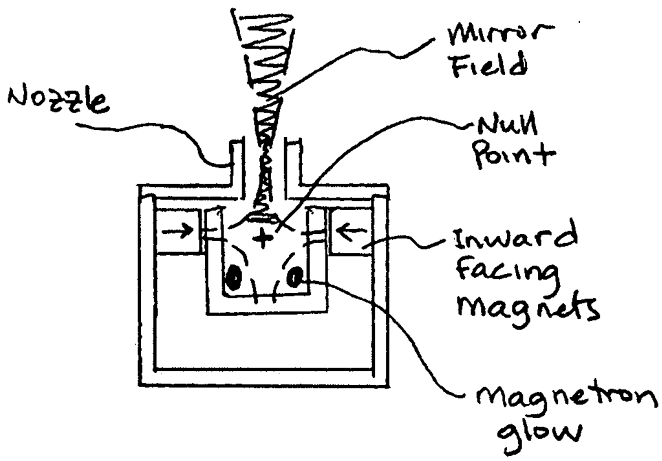
- Unbalanced Planar Magnetron (Type II)
- Magnets facing upward toward substrate
- Null magnetic field point created above planar target

Helmer et al.[ii]



- Sputter target forms container
- Magnets facing upward toward substrate
- Null point above container
- No physical reduced dimension nozzle over container

Madocks' Plasma Beam Source Patent Application



- Magnets face inward
- Null magnetic field point inside discharge cavity

Physical nozzle over cavity:

- o Blocks sputtered flux from exiting cavity
- o Blocks external gas from entering cavity.
- o Allows different pressures to exist between cavity and vacuum chamber.

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[i] B. Window and G.L. Harding, Ion-assisting magnetron sources: Principles and uses, Journal of Vacuum Science and Technology A, Volume 8, May/June 1990

[ii] Helmer et al., US Patent 5,482,611, Physical Vapor Deposition Employing Ion Extraction from a Plasma, Issued January 9, 1996